Energy & Environmental Research Center
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April 29, 2021

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
State Capitol, 10th Floor
600 East Boulevard Avenue
Bismarck, ND 58505-0310

Dear Ms. Fine:

Subject: Quarterly Progress Report Entitled "Research in Support of Integrated Carbon Capture and Storage for North Dakota Ethanol Production"; Contract No. R-043-053
EERC Fund 25204

Attached is the subject report for the period of January 1 through March 31, 2021, that shows the progress that has been made with partners of this project.

Thank you for funding this work. If you have any questions, please contact me by phone at (701) 777-5013 or by e-mail at kleroux@undeerc.org.

Sincerely,

DocuSigned by:
F93F81AE98DB40F...
Kerryanne M. Leroux
Principal Engineer, Subsurface R&D

KML/kal

Attachment

c/att: Andrea Holl Pfennig, NDIC

RESEARCH IN SUPPORT OF INTEGRATED CARBON CAPTURE AND STORAGE FOR NORTH DAKOTA ETHANOL PRODUCTION

Quarterly Progress Report

(for the period of January 1 through March 31, 2021)

Prepared for:

Karlene Fine

North Dakota Industrial Commission
State Capitol, 14th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Project Period: June 1, 2020 – November 30, 2021
Contract No. R-043-053

Prepared by:

Kerryanne M. Leroux

Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

April 2021

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RESEARCH IN SUPPORT OF INTEGRATED CARBON CAPTURE AND STORAGE FOR NORTH DAKOTA ETHANOL PRODUCTION

EXECUTIVE SUMMARY

The Energy & Environmental Research Center (EERC) at the University of North Dakota (UND), in partnership with the North Dakota Industrial Commission (NDIC) and North Dakota ethanol producer Red Trail Energy (RTE), is conducting the fourth phase (Phase 4) of a multiphase research and development effort to create the first integrated carbon capture and storage (CCS) system in North Dakota for the reduction of carbon emissions from ethanol production and capitalize on evolving low-carbon-fuel (LCF) markets. The ultimate goal of this effort is implementation of a small-scale (<200,000 metric tons, or tonnes, CO_2 per year) commercial CCS system at an industrial fuel production facility to generate a reduced-carbon ethanol fuel applicable for LCF programs. Actions this quarter toward supporting continuation of the CCS effort at the RTE site include the following:

- RTE submitted a North Dakota CO_2 storage facility permit (SFP) application to North Dakota Department of Mineral Resources (DMR) on February 9, 2021; a compliance review by DMR commenced in coordination with the North Dakota Department of Environmental Quality.

- Finalized geologic exhibits, area of review, supporting plans and the injection well and storage operation components of the North Dakota CO_2 SFP application, incorporating comments following compliance review by the North Dakota DMR.

- Prepared draft outlines for the following Deliverables (D) to describe the processes for developing these components and summarized requirements for a North Dakota CO_2 SFP:
  - D1. CO_2 Storage Characterization Methodologies Report
  - D3. CO_2 Storage Facility Permitting Guidance Document

- A virtual meeting was conducted in March with California LCFS (Low-Carbon Fuel Standard) staff to discuss its CCS protocol requirements and application process.

- Next quarter, updated RTE CCS project outreach materials will be disseminated ahead of the hearing for the submitted North Dakota CO_2 SFP application, anticipated to be scheduled for late May 2021; a potential community open house is being considered for Quarter 3 2021.

The EERC holds an unwavering commitment to the health and well-being of its employees, partners and clients, and the global community. As such, precautionary measures have been implemented in response to COVID-19. Staff continue to carry out project-related activities remotely, and personnel supporting essential on-site laboratory and testing activities are proceeding under firm safety guidelines. Travel has been minimized, and protective measures are being undertaken for those who are required to travel. At this time, work conducted by EERC

employees is progressing with minimal disruption. Challenges posed by economic variability will be met with open discussion between the EERC and project partners to identify solutions. The EERC is monitoring developments across the nation and abroad to minimize risks, achieve project goals, and ensure the success of our partners and clients. In the event that any potential impacts to reporting, scope of work, schedule or cost are identified, they will be discussed and addressed in cooperation with the project partners.

RESEARCH IN SUPPORT OF INTEGRATED CARBON CAPTURE AND STORAGE FOR NORTH DAKOTA ETHANOL PRODUCTION

ACCOMPLISHMENTS

Major Goals of the Project

The ultimate goal of this effort is implementation of a small-scale (<200,000 tonnes CO_2 per year) commercial carbon capture and storage (CCS) system at an industrial fuel production facility to generate a reduced-carbon ethanol fuel applicable for low-carbon-fuel (LCF) programs. To achieve that goal, the Energy & Environmental Research Center (EERC), in partnership with the North Dakota Industrial Commission (NDIC) and Red Trail Energy (RTE), is conducting the fourth phase (Phase 4) of a multiphase research and development effort to create the first integrated CCS system in North Dakota for the reduction of carbon emissions from ethanol production and capitalize on evolving LCF markets.

Accomplishments under These Goals (for the reporting period)

In summary, Phase 4 will collect the data necessary to advance the RTE case study for ultimate implementation of the first integrated ethanol and CCS facility in North Dakota. This research and complementary RTE activities will advance the CCS effort toward a financial investment decision on commercial implementation. The expected results of this supporting research will, therefore, ensure secure injection and storage economic viability, regulatory compliance, public knowledge sharing, and generation of a North Dakota Class VI blueprint to effectively assist implementation of CCS by other North Dakota renewable energy or biofuel producers.

Specific research objectives for this subtask are to generate 1) a summary of site-specific geologic evaluation steps necessary to finalize CCS designs that ensure safe injection and storage; 2) contrasts–comparisons of federal and other state-level incentive requirements with the North Dakota Class VI Program, to establish potential business cases and ensure economic viability; 3) detailed interpretations and documentation needs to ensure regulatory compliance for CO_2 injection and storage; 4) community engagement and information dissemination, assessing impact, to ensure public knowledge sharing; and 5) documentation of pertinent outcomes to generate a North Dakota Class VI blueprint, to effectively assist implementation of CCS by other North Dakota renewable energy or biofuel producers.

Task 1.0 – Geologic Characterization and Evaluation

This task comprises the remaining research activities needed to conduct an in-depth investigation of the geology of the RTE site, necessary for the preparation of a compliant North Dakota carbon storage permit package (Task 4). Data and samples have been collected from a stratigraphic test well drilled at the RTE CCS site (RTE-10) in March 2020. This activity includes laboratory analyses of collected geologic core samples (e.g., petrophysical, geomechanical, etc.), laboratory analyses of collected reservoir fluid samples (e.g., chemistry,

salinity, etc.), and data processing of collected downhole geophysical logging and formation testing results (e.g., dipole sonic, pulsed-neutron logging, etc.). Results of these activities also provided necessary inputs for Tasks 2–4. The process of data needs identification, subsequent collection, and logistics associated with these activities will be detailed in Deliverable 1 (D1) CO_2 Storage Characterization Methodologies Report, as a guide to other biofuel producers.

Significant accomplishments for Task 1.0 during the reporting period include the following:

- Finalized geologic exhibits for a North Dakota CO_2 SFP application, addressing comments following review by the North Dakota Department of Mineral Resources (DMR) for compliance:
  - Geologic exhibits address 1) data and information sources; 2) storage reservoir; 3) confining zones; 4) faults, fractures, and seismic activity; and 5) potential mineral zones as required by the North Dakota CO_2 SFP application.

- Prepared the D1 report outline to describe the process for developing the geologic exhibits required for a North Dakota CO_2 SFP.

Task 2.0 – Modeling and Simulation

Task 1 results were used to update geologic interpretations of the target CO_2 storage reservoir and seal(s) as well as refine injection designs and CO_2 plume predictions essential for permitting. Industry-standard software packages were used in the updates of previous geologic models of the study area and development of new CO_2 injection simulation cases. Capture and transport infrastructure designs were reviewed to accommodate finalized injection designs. The processes by which data are integrated into geologic models and used to develop predictions of plume behavior will also be described in D1.

Significant accomplishments for Task 2.0 during the reporting period include the following:

- Finalized area of review (AOR) and associated components for a North Dakota CO_2 SFP application; addressed comments following compliance review by the North Dakota DMR:
  - AOR section addresses 1) AOR delineation; 2) corrective action evaluation; and 3) protection of underground sources of drinking water, as required by the North Dakota CO_2 SFP.

- Began generating the process descriptions of the modeling and simulation methods for the D1 report.

Task 3.0 – Business Case Analysis

LCF programs and other CCS incentives (e.g., Section 45Q) continue to be assessed to develop a business case analysis of North Dakota ethanol CCS commercial application. This task

includes investigations of business cases implementing requirements from various LCF/incentive programs into North Dakota carbon storage permits to establish synergistic relationships between multiple oversight authorities at state and federal levels. This integration will allow North Dakota to provide verification for other oversight authorities through North Dakota's established permitting and oversight process. Analysis of these synergies will include a "crosswalk," or contrast–comparison, of the various programs and recommendations for leveraging symbiotic opportunities while also ensuring full compliance (D2. CCS Business Crosswalk).

Significant accomplishments for Task 3.0 during the reporting period include the following:

- A virtual meeting was conducted March 16 with California LCFS staff to discuss CCS protocol requirements for the CCS permanence certification application process; in summary:
  - Third-party reviewers require LCFS–CCS staff approval, which can take 1–2 months assuming all criteria are met.
  - Process following application submittal: 1) completeness check; 2) technical review; and 3) redacted version posted for 30-day public review, only addressing "substantive comments that are technical."
  - Estimated LCFS–CCS review time frame is 12 months; staff is willing to review applications prior to third-party review for completeness.

- CCS tax credit (Section 45Q) final regulation was submitted for publication to the Federal Register in January 2021: https://home.treasury.gov/news/press-releases/sm1227.

Task 4.0 – Carbon Storage Permitting

Final documentation is being prepared to satisfy a North Dakota CO_2 SFP as detailed in NDAC §43-05-01. The North Dakota permit covers multiple design aspects developed to ensure safe and effective site assessments, carbon storage operations, and postinjection monitoring. The draft documents initiated to satisfy the CO_2 SFP application are being finalized with the proposed characterization results from Task 1 and reviewed with North Dakota DMR such that RTE may submit for approval to start final CCS implementation (D3. CO_2 Storage Facility Permitting Guidance Document).

Significant accomplishments for Task 4.0 during the reporting period include the following:

- Addressed comments by the North Dakota DMR to finalize the remaining sections for a North Dakota CO_2 SFP application including Supporting Permit Plans and the Injection Well and Storage Operations sections.
  - Supporting Permit Plans include required discussion of 1) an emergency and remedial response plan, 2) financial assurance demonstration, 3) worker safety plan, 4) testing and monitoring plan, 5) well casing and cementing program, 6) plugging plan, and 7) postinjection site and facility closure plan.

  - Injection Well and Storage Operations sections(s) include required discussion of 1) the RTE-10 well proposed operational parameters, 2) the RTE-10 well proposed completion procedure to conduct injection operations, and 3) the RTE-10.2 well proposed procedure for monitoring well operations.

- Began generating the D3 report outline to describe the process for developing these sections required for a North Dakota CO_2 SFP.

Task 5.0 – CCS Community Outreach

The EERC continues to support local RTE efforts for public acceptance of North Dakota CCS targeted to landowners, Richardton and adjacent communities, city/county commissions, and regional educators. Areas of focus include stakeholder engagement activities in support of research and fieldwork, production and dissemination of informational materials, community outreach, implementation of a system to track engagement activities and acquire feedback, and ongoing assessment of progress. Building on the outreach experience and materials from 2019 activities, the project team is developing additional outreach materials and media and updating the project Web pages. The experience and materials developed will be incorporated into D4. CCS Outreach Tool Kit.

Significant accomplishments for Task 5.0 during the reporting period include the following:

- Completed EERC blog article, "Science Says 'Go!' at the Red Trail Energy Ethanol Plant," summarizing the geologic evaluation conducted in Tasks 1 and 2. Published on February 4, 2021.

- Completed EERC blog article, "Red Trail Energy Submits North Dakota Carbon Dioxide Storage Facility Permit Application," announcing the SFP application submission. Published February 9, 2021.

- The project webpage, formally hosted on the EERC's Plains CO_2 Reduction (PCOR) Partnership website, is now hosted on the EERC's main website. The website shortcut (undeerc.org/RedTrailEnergy) points to the new URL: https://undeerc.org/research/projects/redtrailenergyccs.html

- Revised project fact sheets to include RTE CCS activities conducted to date (e.g., two wells now drilled).

- Completed preparations for Stark County and Richardton City Commission meetings to provide voluntary updates on RTE CCS project progress:
  - Contacted commission auditors requesting placement on the meeting agenda for RTE presentation of project status for April.
  - Prepared content, including the updated fact sheets, a press release for any press attending the meeting, and talking points for RTE.

Task 6.0 – Management and Reporting

This task includes managing project activities and ensuring coordination and planning of the project with participants and sponsors.

Significant accomplishments for Task 6.0 management during the reporting period include the following:

- EERC personnel conducted an interview with the University of North Dakota online news source "UND Today" on February 22, 2021, featured in in a piece entitled "New Milestone for Carbon Capture and Storage: Red Trail Energy and EERC near Commercialization of CO_2 Storage Technology."

- Participated in and presented project summary at the 15th International Virtual Conference on Greenhouse Gas Control Technologies (GHGT-15), March 15–18, 2021:
  - Completed and submitted a project paper entitled "First North Dakota CCS Project: Advancing North Dakota Ethanol Economics."
  - Collaborated with RTE to develop a presentation, which was recorded and presented virtually on March 17, 2021.

Plan for the Next Reporting Period to Accomplish the Goals

All activities will continue progressing toward project goals. A detailed outline for D1 and D3 will be completed for RTE review, and content development will begin. Discussions will continue with California LCFS staff to detail requirements for the CCS permanence certification application process. Preparation of outreach materials will continue ahead of the DMR public hearing, anticipated to be scheduled for late May 2021; planning may begin for a potential community open house in Q3 2021.

PRODUCTS

Publications, Conference Papers, and Presentations

A project-related conference paper and presentation were generated for the GHGT-15 event; see Appendix A for a copy of the presentation.

Web Site(s) or Other Internet Site(s), Technologies or Techniques, Inventions, Patent Applications, and/or Licenses

Revised the RTE CCS project website (undeerc.org/RedTrailEnergy) for up-to-date information, including a link to the previously mentioned blogs as well as the newly updated fact sheets.

CHANGES/PROBLEMS

The EERC is operational and open for business. Personnel that are not essential for on-site operations have transitioned to working from home. Essential project, laboratory, and field-based activities are proceeding with the incorporation of the Centers for Disease Control and Prevention (CDC), the state of North Dakota, and University of North Dakota guidelines associated with COVID-19, and mitigation measures have been implemented.

In collaboration with project partners, the EERC is continually assessing potential impacts to project activities resulting from COVID-19 and/or the U.S. economic situation.

APPENDIX A

GHGT-15 PRESENTATION

First North Dakota CCS Project: Advancing North Dakota Ethanol Economics

ghgt-15
15 - 18 MARCH 2021

March 17, 2021

Dustin Willett, Chief Operating Officer
Red Trail Energy, LLC, North Dakota USA

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Outline

- Introduction
- Incentives
- Capture
- Characterization
- Permitting
- Outreach
- Next Steps
- Questions

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Introduction

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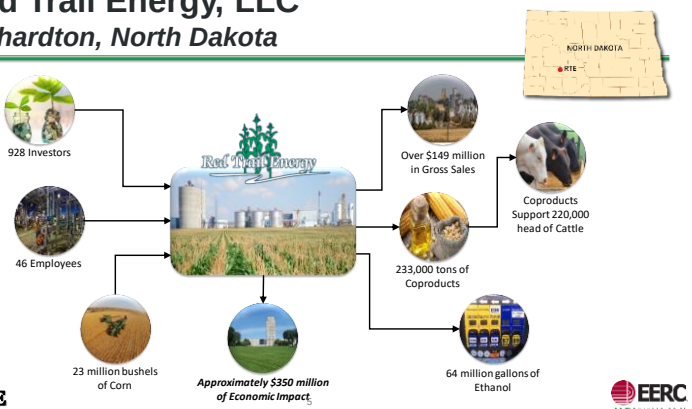
Red Trail Energy, LLC
Richardton, North Dakota



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Evolving Ethanol Markets

Low-Carbon Fuels

- A transportation fuel having a lower "carbon intensity" than conventional petroleum fuels
- Ethanol, natural gas

Photograph by Lars Plougmann

Carbon Intensity (CI) by Fuel Type

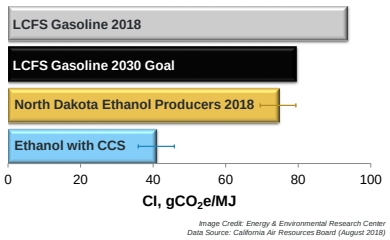

Image Credit: Energy & Environmental Research Center
Data Source: California Air Resources Board (August 2018)

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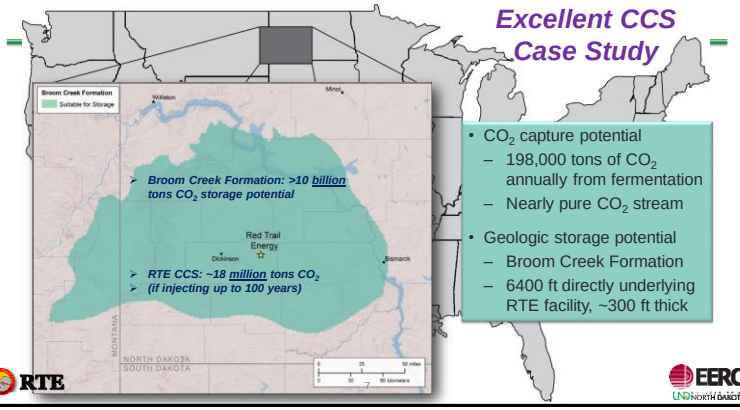
RTE Site: *Excellent CCS Case Study*



- *Broom Creek Formation: >10 billion tons CO_2 storage potential*
- *RTE CCS: ~18 million tons CO_2*
- *(if injecting up to 100 years)*

- CO_2 capture potential
  - 198,000 tons of CO_2 annually from fermentation
  - Nearly pure CO_2 stream
- Geologic storage potential
  - Broom Creek Formation
  - 6400 ft directly underlying RTE facility, ~300 ft thick

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RTE CCS: *Partners and Progress*

- The first North Dakota CO_2 Storage Facility (Class VI) Permit application submitted February 9, 2021

EERC RTE renewable ENERGY PROGRAM

U.S. DEPARTMENT OF ENERGY | NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

TRIMERIC CORPORATION

Schlumberger CMG COMPUTER MODELLING GROUP LTD.

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Incentive Programs Boost Ethanol CCS Economics

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CO_2 Market Value

Low-Carbon Fuel Programs

- California's Low-Carbon Fuel Standard (LCFS)
- Oregon's Clean Fuels Program
- British Columbia Renewable & Low-Carbon Fuel Requirements Regulation

USA IRS Tax Incentive

- Up to \$50/tonne CO_2 for dedicated storage
- Construction before 2024
- Credits allowable for 12 years

Storage Type	2021	2022	2023	2024	2025	2026+
Dedicated Storage, $/tonne	34.81	37.85	40.89	43.92	46.96	50.00*
EOR, $/tonne	22.68	25.15	27.61	30.07	32.54	35.00*

** To remain constant in value for 2027 and thereafter (adjusted for inflation).*

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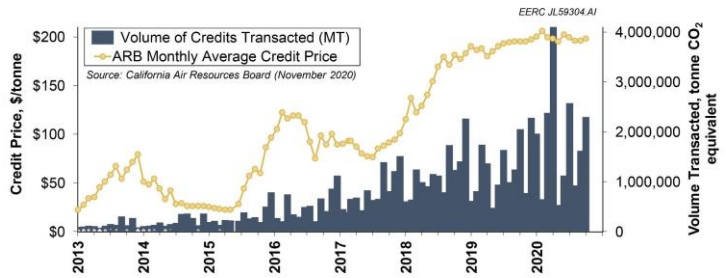
California's LCFS Credit Market



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Capture Facility Moves Closer to Construction

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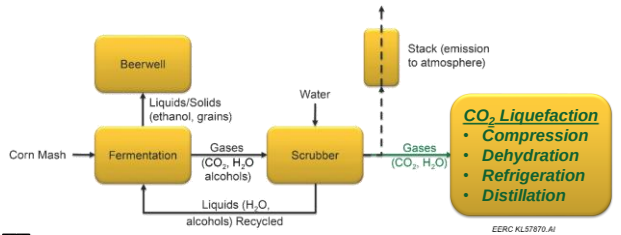
Capture System Commissioned

RTE CO_2 Liquefaction System:

- *700 tonnes/day CO_2*
  - *1500 psi (~100 bar)*
  - *40°F (4°C)*
- *~USD$20 million installed*
- *Start-up ~Q1 2022*



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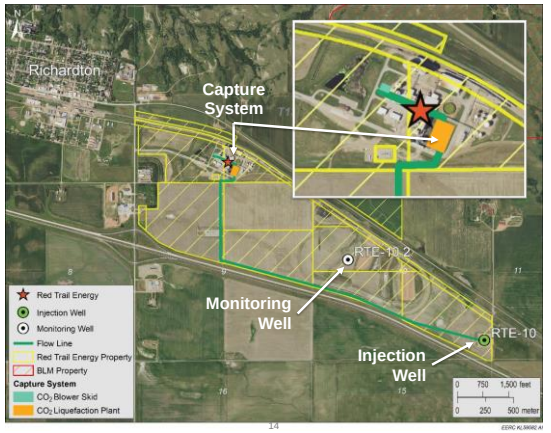

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Site Characterization and Monitoring Reduce Risk and Increase Confidence

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Baseline Near-Surface Monitoring

Accomplishments

- ✓ Near-surface environment defined (e.g., natural seasonal variability)
- ✓ Periodic compositional analyses
  - Existing water wells (435–1800-ft depth)
    - ♦ **pH, alkalinity, total dissolved solids,** major cations, major anions, dissolved and total organic carbon, and isotopic analysis
  - Soil gas (3.5-ft depth)
    - ♦ **CO_2, O_2, N_2,** and isotopic analysis

Outcomes

- ➢ Identified baseline of key indicators (**bold**) for long-term monitoring
- ➢ Generated required components for Class VI permit monitoring plan

Image Credit: Energy & Environmental Research Center

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Geophysical Survey Provides More Clarity of the Subsurface

Accomplishments

- ✓ Conducted ~8-mi^2 seismic survey near Richardton, North Dakota, in March 2019.
  - Vibroseis trucks, array of surface receivers
- ✓ Verified Broom Creek Formation for potential CO_2 storage target
  - 6400-ft depth, ~295-ft thickness

Outcomes

- ➢ Determined location for CCS stratigraphic test and potential injection/monitoring wells
- ➢ Generated required components for Class VI permit geologic characterization

Images Credit: Energy & Environmental Research Center

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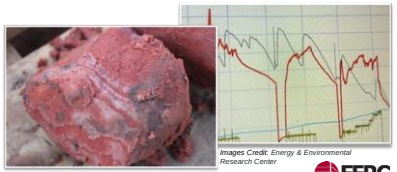
Stratigraphic Test Well Completes Data Needs

Accomplishments

- ✓ ~931-ft total core (98% recovery)
  - Cap + underlying rock = ND Class VI-compliant
- ✓ Laboratory analyses
  - ***Core:*** petrophysical, geomechanical, etc.
  - ***Reservoir fluid:*** chemistry, salinity, etc.
- ✓ Geophysical logging and formation testing (e.g., dipole sonic, pulsed-neutron, etc.)

Outcomes

- ➢ Verified injectivity, capacity, and containment
- ➢ Generated required components for Class VI permit geologic characterization



Images Credit: Energy & Environmental Research Center

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Preparing the First North Dakota UIC Class VI Permit Application

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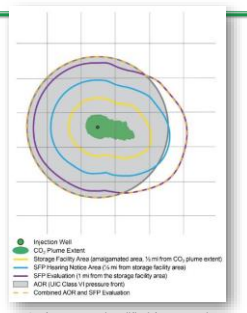
Geologic Modeling and Simulation



Surface terms (modified from DMR) regarding ND permit requirements (Connors and others, 2020)

Accomplishments

- ✓ Update geologic interpretations of the target CO_2 storage reservoir and seal(s)
- ✓ Refine injection designs and CO_2 plume predictions

Outcomes

- ➢ Verified/finalized capture designs for CO_2 injection conditions
- ➢ Determined area of review (AOR), pore space owners
- ➢ Finalized required components for Class VI permit geologic characterization, AOR, and monitoring/postinjection plans

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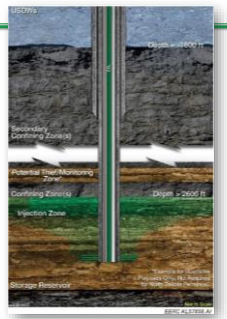
RTE Submitted First Class VI Application for First CCS Operations in North Dakota

North Dakota CO_2 Storage Facility Permit [Class VI] Checklist – ✓Done!

- ❑ Pore Space (Affidavit + Maps)
- ❑ Geologic Exhibits (a.k.a. Technical Evaluation)
- ❑ AOR Delineation (Maps + Corrective Action Plan)
- ❑ Emergency and Remedial Response Plan
- ❑ Worker Safety Plan
- ❑ Corrosion Monitoring and Prevention Plan
- ❑ Leak Detection and Reporting Plan
- ❑ Well Casing and Cementing Program
- ❑ Testing and Monitoring Plan
- ❑ Well-Plugging Plan
- ❑ Postinjection Site Care and Facility Closure Plan
- ❑ Injection Well and Storage Reservoir Information



Subsurface terms regarding ND permit requirements (Connors and others, 2020)

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Building CCS Support in North Dakota Through Outreach

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CCS Outreach in Rural Communities

Accomplishments

- ✓ Open houses in Richardton, North Dakota
  - March 2019
  - December 2019
- ✓ Landowner results packets
  - Geophysical survey report (fact sheet format)
  - Sampling results (May, Aug, Nov)
- ✓ Alternative approaches to in-person outreach activities
  - Informational videos, virtual question and answer forums, and a series of media/materials releases, etc.

Outcomes

- ➢ Posters, presentations, fact sheets, landowner letters, public webpage, etc.
- ➢ **Public awareness and acceptance for CCS in North Dakota**

Image Credit: Energy & Environmental Research Center

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Next Steps: Approvals and Operations

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RTE CCS Project: Next Steps

❑ **Approvals**
- ***North Dakota Class VI Permit***
  - ♦ Public hearing, mid-2021
- ***LCFS CCS Certification***
  - ♦ Develop and submit application
- ***U.S. Environmental Protection Agency (EPA) Monitoring, Reporting, and Verification (MRV) Plan***
  - ♦ To claim Section 45Q tax credits

❑ **Installations**
- ***CO_2 liquefaction facility and pipeline***
  - ♦ Integrate with CO_2 injection, geologic storage system
- ***Near-surface monitoring equipment***
  - ♦ Groundwater wells, soil gas stations

Image Credit: Energy & Environmental Research Center

➢ ***Start CCS Operations!***

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Questions?

Image Credit: Energy & Environmental Research Center

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